THE CLEAN AIR ACT AND THE U.S. ECONOMY

Final Report
of Results and Findings

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By
Dale W. Jorgenson Associates
Cambridge, Massachusetts

Dale W. Jorgenson
Richard J. Goettle and Daniel E. Gaynor
Peter J. Wilcoxen and Daniel T. Slesnick

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THE CLEAN AIR ACT AND THE U.S. ECONOMY

Executive Summary

The Clean Air Act and its subsequent amendments to 1990 were legislative initiatives directed toward internalizing the externalities of air pollution. As a result, they imposed costs on producers and consumers as economic activities were brought into compliance with statutory requirements. The analyses covered in this report examined the consequences of these costs for economic performance and welfare. They were based on the application of a multi-sector, inter-temporal, general equilibrium model of the U.S. economy. The goals were to establish how the economy might have evolved had there been no Clean Air Act and to provide a measure of the welfare loss associated with the costs of compliance.

The costs arising from these enactments adversely affected economic performance. Real consumption and income ultimately would have been one percent higher in their absence. The impacts were not uniform with industries like motor vehicles, petroleum refining and electric utilities particularly affected. A lower capital stock was the principal cause of these effects. The compliance costs reduced real investment in productive capacity, thereby reducing the economy's rate of capital formation and, through economic restructuring, slowing its rate of productivity growth. For a family of size four headed by a white male, age 35-44, living in the urban Northeast, the welfare gain of not having to absorb the costs of compliance was estimated to be almost $(1990) 8,300 or 0.8 percent of lifetime expenditure. For society as a whole, the estimated change in welfare was in the range of $(1990) 500 to 700 billion depending on the indicator chosen. And, the compliance costs were found to be regressive to income-expenditure.

Two-thirds of the damages were determined to arise from the costs associated with stationary sources of air pollution; the remaining one-third was related to the costs arising from mobile source initiatives. However, alternative estimates of the mobile source costs doubled these adverse impacts, raising the total damages by over thirty percent. Observed technical biases in factor use and endogenous productivity growth, features of the simulation methodology, accounted for ten to twenty percent of the measured impacts, leaving eighty to ninety percent attributable solely to the compliance costs. Finally, the estimated consequences of compliance were essentially insensitive to changes in the assumed behavior of foreign savers and investors.

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THE CLEAN AIR ACT AND THE U.S. ECONOMY

1. Introduction

This analysis examines the economic implications of complying with the provisions of the Clean Air Act (CAA). It is incomplete in the sense that only the direct and indirect costs of compliance were considered; any benefits to society from this compliance were not included. The effects were measured by comparing a simulation of the economy over the interval, 1973-2060, in which the Clean Air Act was present, to one in which a substantial portion of the direct costs of compliance were eliminated.

In addition to this central analysis, several related issues were considered and the economic implications of these similarly were determined. These issues focused on:

1) Isolating the effects of EPA's mobile and stationary costs and contrasting the former with chose arising from other available estimates;

2) Examining the role of endogenous technical change or productivity growth within the simulation results;

3) Ascertaining the importance of the maintained hypothesis for foreign savings and investment behavior to the overall response.

The results presented herein deal with the consequences of these phenomena for the growth and structure of the U.S. economy. Additional results focus on three dimensions of economic welfare. The first relates to the impacts of the general equilibrium costs on the welfare of individual types of households, distinguished by their demographic attributes. The second concerns the aggregation of these individual effects into a summary measure of the overall welfare change associated with these costs. The final dimension pertains to the regressivity or progressivity of the direct CAA costs and the economic adjustments to them.

2. Methodology

The results that follow are based on simulations conducted with the Jorgenson-Wilcoxen-Slesnick (JWS) model, a disaggregated, econometrically estimated, inter-temporal general equilibrium model of the United States economy. The key features of this model are described below.

Production is disaggregated to 35 separate commodities produced by one or more of 35 industries. The input structure of each producing sector is represented by an econometrically-estimated, flexible functional form that fully captures substitutions among inputs and industry-level biased technical change.

Household consumption by commodity is the result of a three-stage inter-temporal optimization process in which full wealth (financial wealth, future labor income and the imputed value of leisure) first is allocated over time (with perfect foresight on prices and interest rates). Each period's full consumption then is split between goods and leisure, giving rise to the determination of labor supply. Finally, goods expenditures are allocated and mapped among capital, labor and the various categories of goods and services based on an aggregated system of individual, demographically-defined household demand equations. Like production, all household behavior is econometrically estimated and flexible, capturing both inter- and intra-temporal substitutions and allowing income-induced changes in expenditure patterns that are independent of price changes.

Capital accumulation is the outcome of inter-temporal behavior on the part of households and firms. Households and businesses determine the amount of savings available in each period as the difference between income and expenditure and firms invest until the returns on additional investment equal the cost of new capital goods. New capital, which is perfectly malleable across households and industries, is structured according to an econometrically-estimated model of investment behavior allowing substitutions between different commodity inputs. The total supply of capital at any time is fixed by past investment behavior. Thus, the interest rate adjusts to align savings and investment and to equilibrate the commodity-based price of new capital goods with the discounted value of future capital rental prices.

Government expenditures adjust to achieve balance between government revenues, which arise from exogenous tax rates applied to endogenous levels of economic activity, and the exogenously-specified government budget deficit.

The exchange rate adjusts to bring net exports into line with the exogenously specified current account balance. Imports are considered imperfect substitutes for similar domestic commodities and compete on price, import prices being exogenous. Export demands depend on foreign incomes (exogenous) and the foreign prices of U.S. exports, which arc determined largely by domestic prices and the exchange rate.

Economic activity is organized in an inter-industry framework in which the demands for and supplies of each commodity as well as capital and labor balance in both value and quantity terms.

The household demand system is consistent with the theory of consumer behavior with budget shares as functions of prices, total expenditure and household characteristics. The system involves substantial demographic detail and permits the underlying data to reveal the nature and intensities of the response surfaces. Because the household demand system is integrable, household welfare is recoverable as are household expenditure functions. Micro and macro behaviors arc linked through the exact aggregation of expenditure functions. Cardinal measures of household welfare and expenditures and the acceptance of interpersonal welfare comparisons permit aggregation. Social welfare, thus, is based on the level and distribution of individual welfare, the weights being determined through appeal to an equity redistribution principle. Accordingly, welfare assessments of public policy are consistent with the theory of social choice.

3. Removing the Costs of Compliance

The CAA compliance costs included in this analysis cover capital and operating and maintenance outlays for nonfarm stationary sources. Recovered costs associated with pollution control in manufacturing offset O&M outlays. The compliance costs also include government expenditures for pollution abatement, research and development, and regulation and monitoring. Capital, maintenance and fuel-related charges for mobile source air pollution control complete the compliance cost data. Only private R&D outlays are omitted from consideration since there is no basis for allocating them to specific industries or specific purchases. The sources of these data and the database of air pollution control expenditures developed for this analysis are presented in Appendix A of this report. A summary of the aggregate cost information appears in Table 3.1.

Annual CAA compliance costs avenge $(1990) 24.8 billion over the period 1973-1990. Of this, stationary source capital and net operating expenditures average $(1990) 7.4 billion and $(1990) 7.1 billion, respectively. Government outlays average just over $(1990) 0.7 billion. The total compliance costs for mobile sources account for almost forty percent of all compliance costs or $(1990) 9.6 billion of the average total expenditure. (The private R&D expenditures omitted from consideration average $(1990) 1.6 billion, 1973-1990, or 10% of the total private costs for stationary sources.)

These costs average one-third of one percent of total domestic output over the period 1973-1990. However, they are front-loaded, comprising almost one-half of one percent of total output in 1973 and falling to one-quarter of one percent by 1990. In terms of real household income, the costs average just over two-thirds of one percent from 1973-1990.

As environmental regulations are imposed, investment funds are allocated to pollution control activities. If the supply of savings is fixed and if expenditures on pollution control confer no benefits beyond compliance with the law, then there is a loss in ordinary, productive capital accumulation. This occurs for two reasons. First, there is a permanent loss due to the fact that each new unit of capital has a pollution control component embodied in it. Second, there is a transitory loss due to the need to bring existing capital into compliance.

Table 3.1
The Direct Costs Of Compliance

Compliance Costs in $(1990) Billions

	Stationary Sources			
	Capital	Net O&M	Government	Mobile
Average	7.4	7.1	0.7	9.6
1973	9.3	5.5	0.8	15.1
1990	5.2	8.8	0.7	8.9
Peak Value	9.3	8.8	0.8	15.1
Peak Year	1975	1990	1973	1973

	Total CAA Compliance Costs	As a Percent of Real Domestic Output	As a Percent of Real Household Income
Average	24.8	0.33	0.68
1973	30.8	0.48	1.01
1990	23.5	0.25	0.50
Peak Value	30.8	0.48	1.01
Peak Year	1973	1973	1973

To eliminate the capital portion of the CAA compliance costs, the percentage of air pollution abatement investment in total investment first was determined. This then was split in order to separate the windfall loss of having to install abatement equipment on old capital from the permanent effect of the control equipment required for each new unit of capital. It was assumed that the 1990 share of pollution control investment in total investment was a reasonable measure of the permanent effect. This meant that the outfitting of old capital was largely achieved by 1990. This 1990 percentage then was deducted from the overall share of abatement investment in total investment to determine the windfall loss accruing to the owners of existing sources. These percentages are shown in Table 3.2.

The permanent effect was introduced into the JWS model as a reduction in the price of investment goods. This follows from the idea that under the CAA purchasers of capital goods had to buy a certain amount of abatement capital in each unit of new productive capital, thereby increasing the price of new capital goods.

The windfall or transitory effect was applied to the capital accumulation process. In each of the transitory years, 1973-1989, the outlays on abatement equipment for existing sources were returned to increase the ordinary capital formation that occurred that year.

The operation and maintenance of air pollution control devices increases the factor input requirements per unit of output for each affected producing sector. The first step in eliminating the operating portion of the CAA compliance costs was to compute the share of these in the total costs of each industry. (For the manufacturing sectors, these costs were net of any recovered costs associated with the operation of pollution control equipment.) Removal of these costs then was simulated by reducing the unit cost functions in the production model by these proportions. The (net) additional resources required to operate and maintain this equipment were released in a Hicks-neutral fashion; that is, for a given amount of output at fixed factor prices, each industry's input demands will decline in the same proportion.

Unlike the stationary source abatement expenditures, the mobile source compliance costs are borne by the users rather than the producers of selected products. The CAA altered the purchase prices of motor vehicles and other transportation equipment, refined petroleum products and vehicle repair and maintenance. Removal of these costs is accomplished in a manner identical to

Table 3.2
Summary of the Driving Forces of Economic Change

Pollution Control Capital Expenditures
for Stationary Sources
as a Percent of Total Investment

Year	Pollution Control Component for New Capital in Percent	Pollution Control Component for Existing Capital in Percent
1973	0.70	1.00
1974	0.70	1.00
1975	0.70	1.25
1976	0.70	1.09
1977	0.70	0.86
1978	0.70	0.65
1979	0.70	0.67
1980	0.70	0.71
1981	0.70	0.59
1982	0.70	0.62
1983	0.70	0.39
1984	0.70	0.27
1985	0.70	0.15
1986	0.70	0.14
1987	0.70	0.12
1988	0.70	0.07
1989	0.70	0.11
1990	0.70	0.00

In 1975, for example, 1.95 percent of total investment was devoted to pollution control equipment; of this 0.70 percent is assumed to be related to new capital while the remaining 1.25 percent is used to bring existing capital into compliance.

the removal of the stationary source operating costs. First, in each category, the abatement cost share of total expenditure was determined. For motor vehicles and refined petroleum, total expenditures included purchases from domestic and foreign sources. The unit cost functions for the affected sectors along with the relevant import prices then were reduced in proportion to the mobile source cost shares.

A summary of the net operating and maintenance and mobile compliance cost information appears in Table 3.3.

Table 3.3
Summary of the Driving Force of Economic Change

Pollution Control Expenditures
as a Percent of the Value of Industry Output

Sector	Industry Name	1980	1990
1	Agriculture	0.00	0.00
2	Metal mining	0.27	0.59
3	Coal mining	0.26	0.40
4	Oil, gas extraction	0.18	0.46
5	Nonfuel mining	0.28	0.34
6	Construction	0.02	0.02
7	Food	0.01	0.03
8	Tobacco	0.00	0.01
9	Textiles	0.02	0.03
10	Apparel	0.00	0.00
11	Lumber	0.03	0.07
12	Furniture, fixtures	0.01	0.04
13	Paper	0.05	0.12
14	Print, publishing	0.01	0.03
15	Chemicals	0.22	0.20
16	Petroleum	2.24	2.29
17	Rubber, plastics	0.02	0.03
18	Leather	0.01	0.02
19	Stone, clay, glass	0.15	0.19
20	Primary metals	0.49	0.50
21	Fabricated metals	0.03	0.08
22	Nonelectric machinery	0.02	0.02
23	Electronic equipment	0.02	0.03
24	Motor vehicles	2.01	2.55
25	Other transportation eqp.	0.02	0.04
26	Instruments	0.02	0.02
27	Miscellaneous mfg.	0.01	0.02
28	Transportation services	0.06	0.06
29	Communication	0.02	0.02
30	Electric services	1.98	1.44
31	Gas services	0.06	0.18
32	Trade	0.02	0.02
33	F,I,RE	0.02	0.02
34	Services	-0.31	-0.28
35	Gov't. enterprises	0.02	0.02

These expenditures do not include capital outlays for stationary source pollution control equipment. Hence, they cover operating and maintenance expenditures for non-manufacturing, operating and maintenance expenditures net of recovered costs for manufacturing, and all mobile source expenditures, capital and non-capital alike. The mobile source expenditures affect petroleum (sector 16), motor vehicles (sector 24), other transportation equipment (sector 25) and services (sector 34), the latter being adversely affected by the removal of the CAA. The value of industry output is equivalent to its total cost.

4. The Clean Air Act and the U.S. Economy

4.1 Overview of the Simulation Results

There is an immediate economic benefit to businesses and households from eliminating the costs of CAA compliance. Figure 4.1 summarizes these key results. Eliminating the CAA costs leaves real income, consumption and GNP approximately 0.7 percent higher, on average, over the period 1973-1990. The direct and indirect effects boost investment an average of 1.4 percent over this same interval which raises the capital stock by an average of almost 0.9 percent. As shown in Table 4.1, the gain in real consumption accumulates to $(1990) 415 billion and the cumulative gain in real GNP exceeds $(1990) 730 billion. The dominant cause of this economic expansion is additional investment and capital accumulation.

It is assumed throughout this analysis that CAA-related expenditures confer no economic benefit beyond compliance with the law. Restoring the equivalent of these resources to productive use secures a sustained increase in incomes and production as shown in Figure 4.2. For domestic output, this gain averages $(1990) 42.8 billion, 1973-1990, or 0.5 percent of annual domestic production. Operating primarily through greater capital accumulation, the output elasticity associated with the redirection of these resources to private production is approximately 1.5. For real household income, the gains average $(1990) 35.0 billion, or 0.7 percent over the same period. Thus, the income elasticity associated with the elimination of the CAA compliance costs is approximately 1.1.

From a welfare perspective measured over the period 1973-2060, the elimination of the CAA compliance costs secures a gain of $(1990) 493 billion when the greatest weight is given to equality and $(1990) 621 billion when the least weight is given to equality. Indeed, regardless of the weight society places on distributional equality, there is a welfare loss arising from the costs of CAA compliance and their imposition is regressive to total income and expenditure.

Figure 4.1

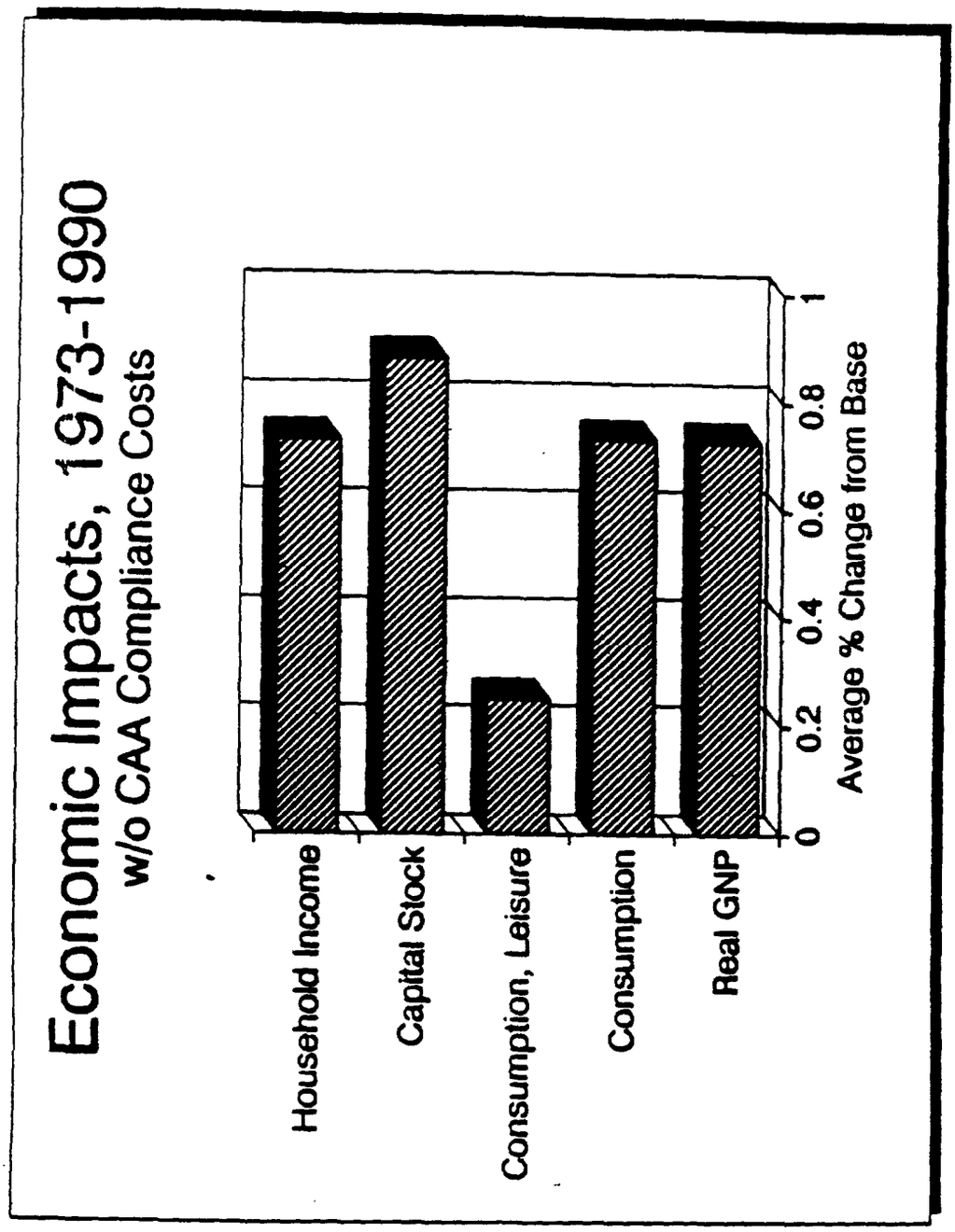

Economic Impacts, 1973-1990
w/o CAA Compliance Costs
Household Income
Capital Stock
Consumption, Leisure
Consumption
Real GNP
0
0.2
0.4
0.6
0.8
1
Average % Change from Base

Table 4.1
Summary of the Cumulative Economic Impact

The Discounted Present Value of Changes in Selected Economic Measures: 1973-1990

Real GNP

Discount Rate	
0	732
1	777
3	880
5	1005
7	1151
10	1429

Real Consumption, Households

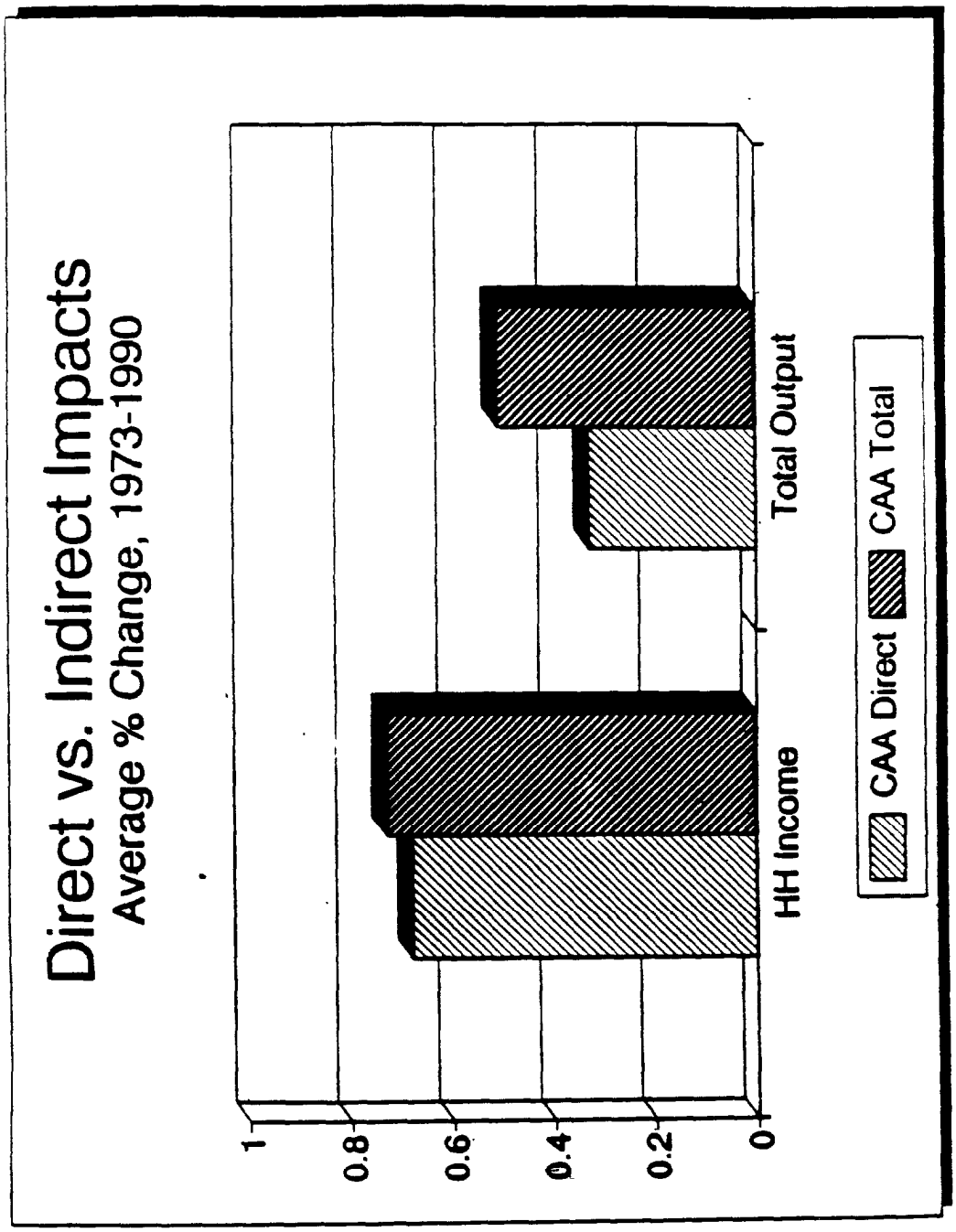
Discount Rate	
0	415
1	439
3	500
5	569
7	653
10	812

Real Consumption, Households and Governments

Discount Rate	
0	562
1	597
3	676
5	769
7	881
10	1091

Discounting to 1990 with the discount rate in percent. Economic measures are in billions of 1990 dollars.

Figure 4.2


Direct vs. Indirect Impacts
Average % Change, 1973-1990
1
0.8
0.6
0.4
0.2
0
HH Income
Total Output
CAA Direct
CAA Total

4.2 The Mechanisms of Economic Adjustment

The macroeconomic consequences of eliminating the direct CAA compliance costs are summarized in Table 4.2 and Figures 4.3 and 4.4. The principal impact is on investment and capital accumulation and the economic restructuring associated with it. Removing the pollution control component of new capital is equivalent to lowering the marginal price of investment goods. Combining this with the windfall gain of not having to bring existing capital into compliance leads to a large initial surge in the economy's rate of return , raising the level of real investment by producers and consumers. More rapid (ordinary) capital accumulation leads to a decline in the rental price of capital services which, in turn, stimulates the demand for capital services. The capital rental price reductions also serve to lower the prices of goods and services and, so, the overall price level. Obviously, the more capital intensive sectors - mining, chemicals and petroleum, the metals industries, the motor vehicle and transportation equipment industries, and public utilities - exhibit larger price reductions.

The price effects from investment changes are augmented by the cost reductions associated with releasing resources from the operation and maintenance of pollution control equipment and by the elimination of higher prices due to regulations on mobile sources. The general equilibrium price effects are illustrated in Figure 4.5 which shows, as expected, that petroleum products, motor vehicles and electric utilities experience the largest price reductions.

As a result of price changes, each dollar flow supports additional quantity purchases. Real consumption, real investment and real purchases by governments all rise. Ultimately, real income and consumption rise by one percent while real investment increases by one and one half percent.

To households, removal of the CAA is viewed as an increase in permanent future real earnings (income) which supports an increase in real consumption in all periods and, generally, an increase in the demand for leisure. The structure of household spending is influenced by the emerging relative price structure, for example, less food and more oil products and durable and, within durables, less furniture and fixtures and more motor vehicles. Households marginally reduce their offer of labor services as the income effects of higher real earnings dominate the substitution effects of lower goods prices.

Table 4.2
Summary of the Economic Impacts

Macroeconomic Consequences

Percentage Change in Real Magnitudes

	1980	1990
GNP	+0.7	+1.0
Consumption	+0.7	+1.0
Investment	+1.4	+1.5
Government	+0.7	+1.1
Net Exports	-24.2	-15.4

Contribution to the Percentage Change in Real GNP

	1980	1990
GNP	+0.7	+1.0
Consumption	+0.4	+0.6
Investment	+0.3	+0.4
Government	+0.1	+0.2
Net Exports	-0.1	-0.2

The Percentage Point Change in Real GNP Growth: 1973-90

The Change in Real GNP Growth	+0.05
Due to the Change in Labor Input	+0.00
Due to the Change in Capital Input	+0.03
Due to Productivity Effects	+0.02

The change in real GNP growth attributable to productivity is due primarily to changes in the economy's input and output composition and only secondarily, and to a much lesser extent, to price-induced changes in productivity growth.

Real variables are measured originally in billions of 1982 dollars.

Figure 4.3

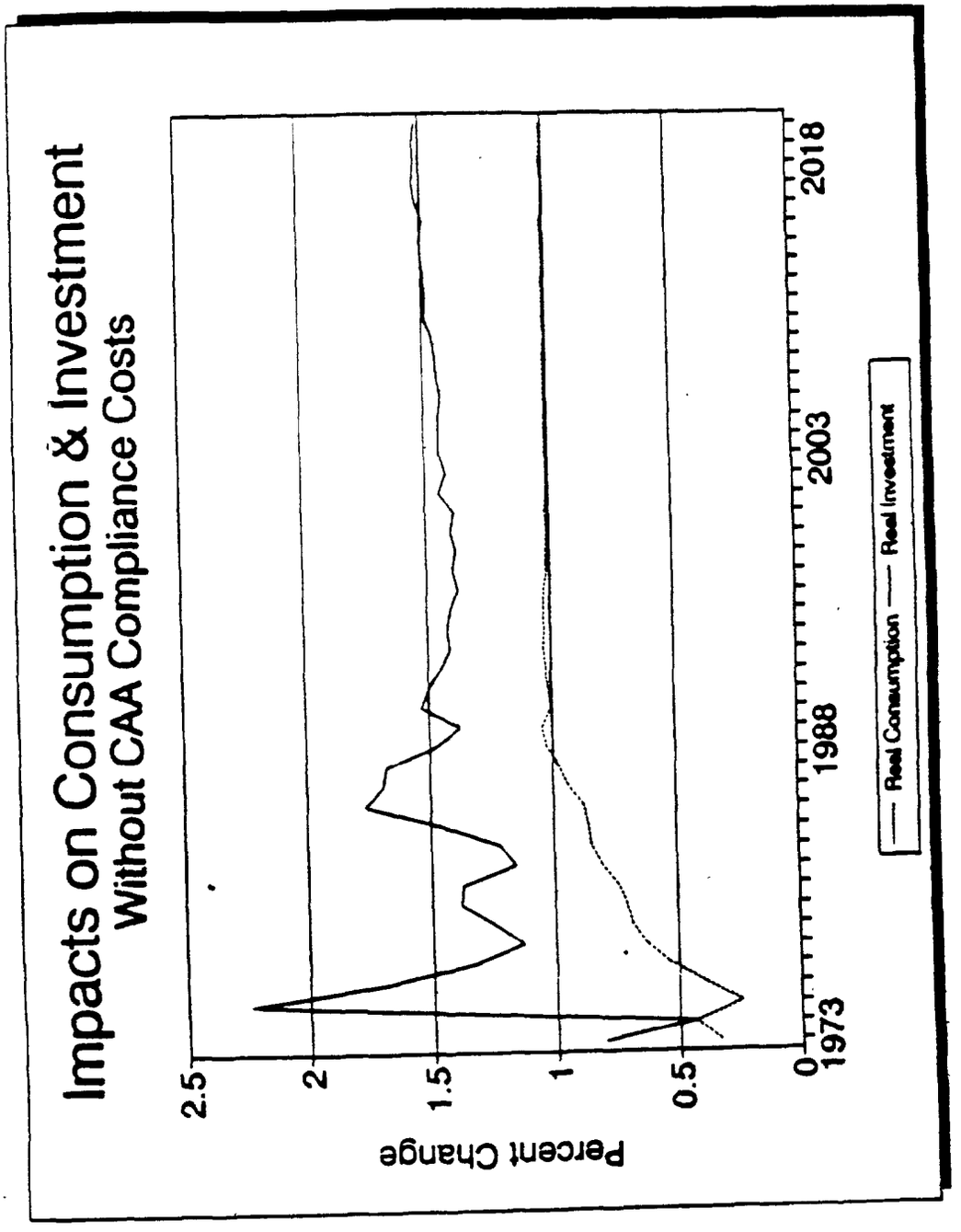

Impacts on Consumption & Investment
Without CAA Compliance Costs
Percent Change
2.5
2
1.5
1
0.5
0
1973
1988
2003
2018
Real Consumption
Real Investment

Figure 4.4

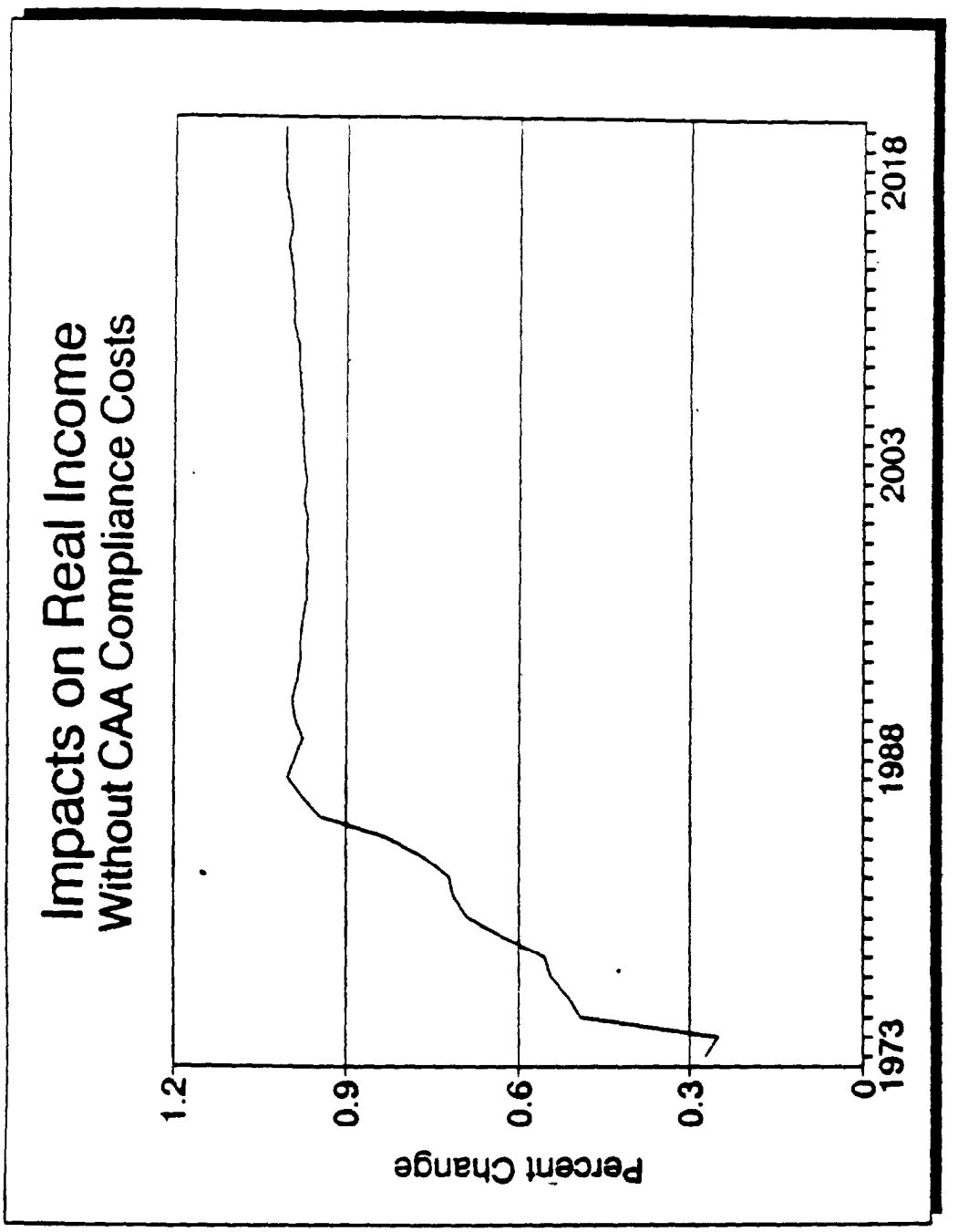
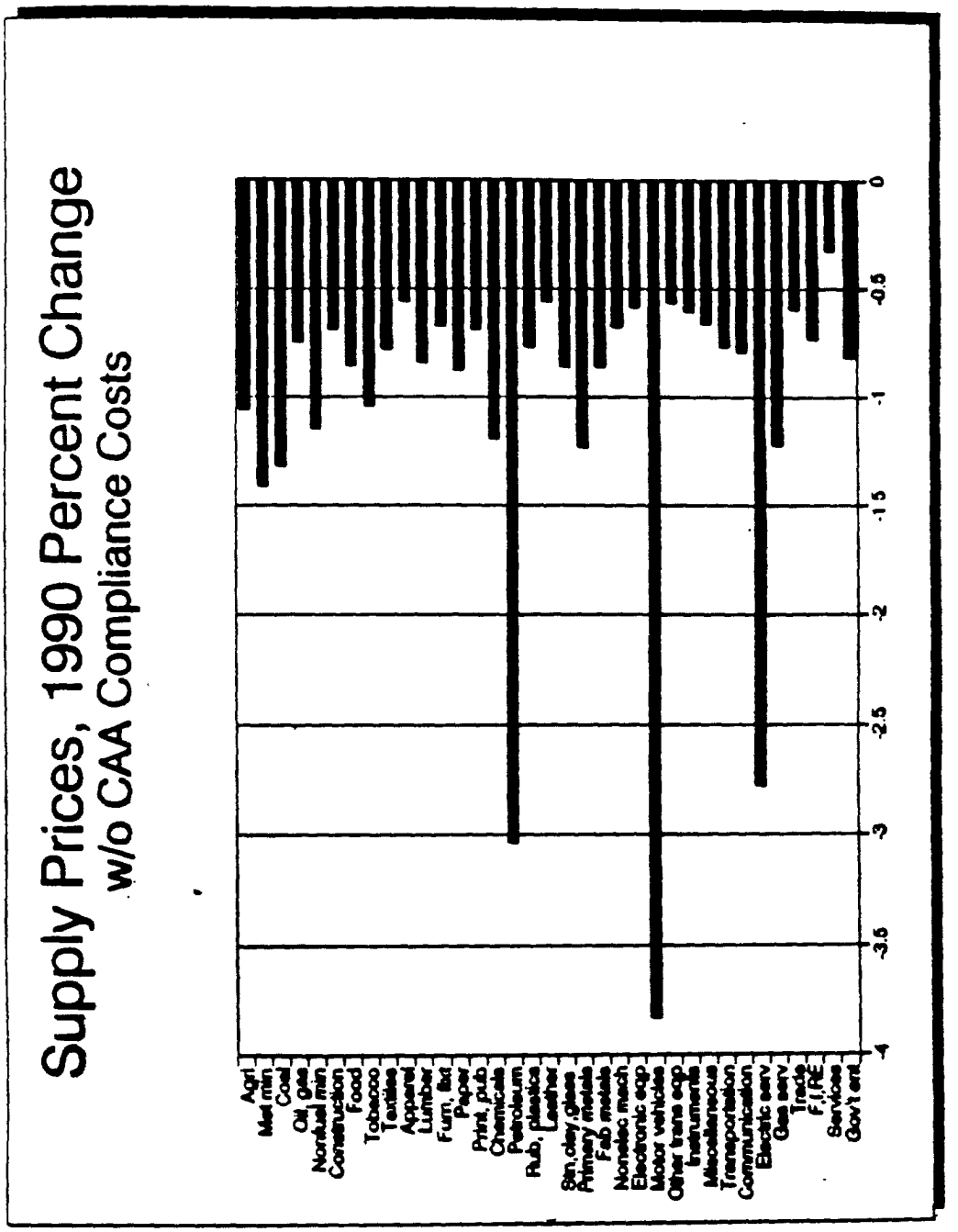

Impacts on Real Income
Without CAA Compliance Costs
Percent Change
1.2
0.9
0.6
0.3
0
1973
1988
2003
2018

Figure 4.5


Supply Prices, 1990 Percent Change
w/o CAA Compliance Costs
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
Agri
Met min
Coal
Oil, gas
Nonfuel min
Construction
Food
Tobacco
Textiles
Apparel
Lumber
Furn. fixt
Paper
Print, pub
Chemicals
Petroleum
Rub, plastics
Leather
Stn, clay, glass
Primary metals
Fab metals
Nonelec mach
Electronic eqp
Motor vehicles
Other trans eqp
Instruments
Miscellaneous
Transportation
Communication
Electric serv
Gas serv
Trade
F,I,RE
Services
Gov't ent

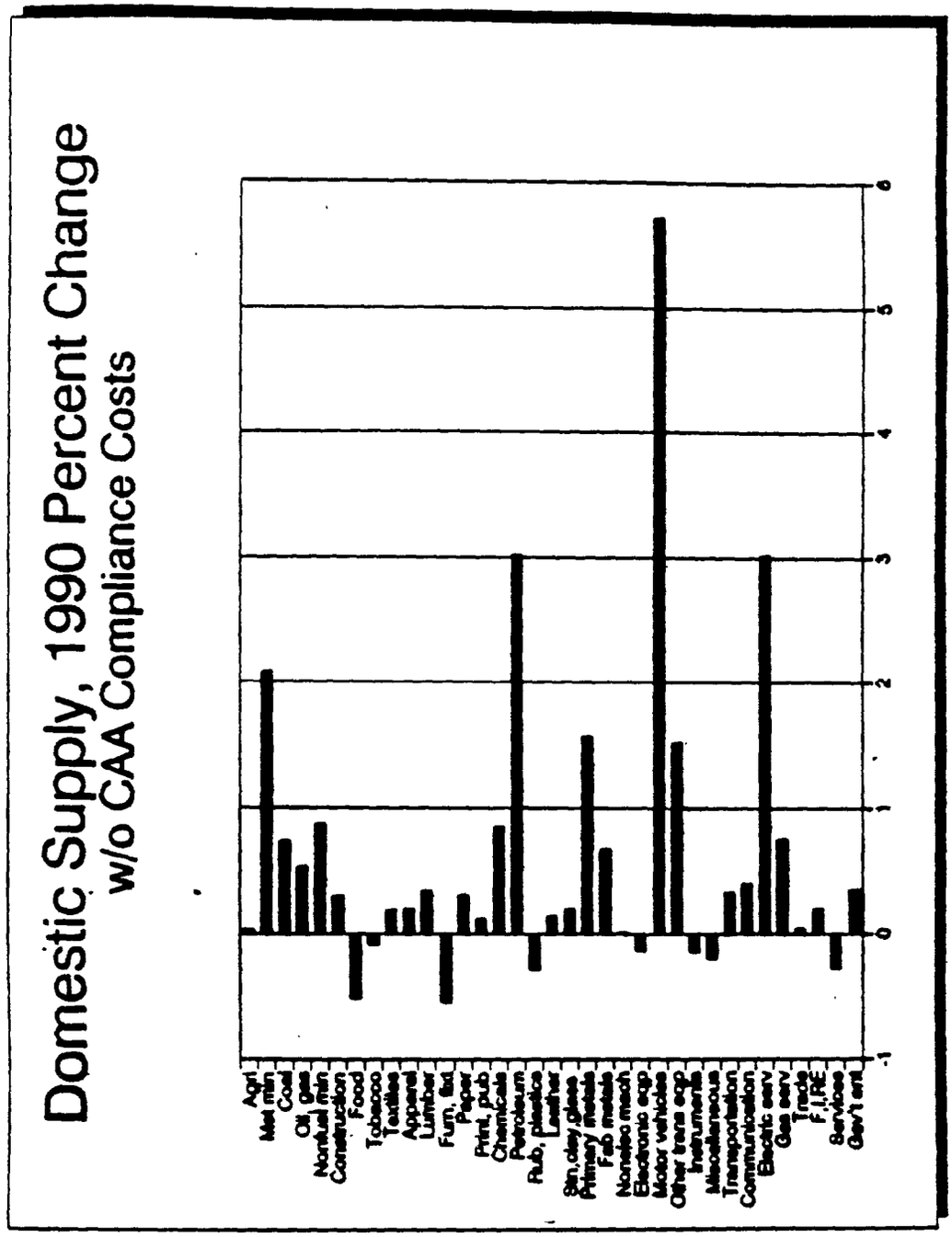
Real spending by governments rises as a consequence of lower commodity prices and the adjustments that hold spending in line with changes in tax revenues and maintain (by assumption) government deficit at previous levels.

Real net exports fall. This occurs as the dollar strengthens by an amount that is sufficient to keep the current account surplus unchanged. Within this overall adjustment, real exports rise as the U.S. becomes more competitive. Real imports also rise because of the stronger dollar and, more importantly, because of the decline in motor vehicle and refined petroleum import prices that accompany removal of the CAA compliance costs.

Finally, productivity effects offer additional supply-side benefits to the removal of compliance costs. These arise mainly from the input and output restructuring that takes place. Relative price changes alter the input patterns within each producing sector and change the level of input-to-output productivity. Relative prices changes and the altered structure of final demand, both within and across spending categories, change the output composition of the economy. Since productivity differs among industries, this compositional change affects overall productivity. This output effect on overall productivity also appears in the input-to-output relation between the intermediate use of goods and services and final demand (value added). Lastly, there are smaller effects as lower factor prices increase the endogenous rates of productivity growth in those industries that are factor-using. Lower rental prices for capital benefit the capital-using sectors, lower materials prices benefit the materials-using sectors and lower energy prices benefit the energy-using sectors. Upon removal of the CAA compliance costs, economic growth averages 0.05 percentage points higher over the interval 1973-1990. The increased availability of capital accounts for sixty percent of this increase while the combination of aforementioned productivity changes account for the remainder. Thus, the principal effects arising from the costs associated with clean air initiatives are to slow the economy's rate of capital accumulation and, by restructuring economic activity, its overall rate of productivity growth.

As indicated above, eliminating the CAA costs affects the composition of domestic supply. Relative price changes alter the input patterns within each producing sector which combines with the altered structure of final demand, both within and across demand categories, to change the output composition of the economy. These changes are summarized in Figure 4.6. As expected, those commodities whose cost structures are most affected by the CAA experience the largest increases in demand and supply. These include chemical and petroleum

Figure 4.6


Domestic Supply, 1990 Percent Change
w/o CAA Compliance Costs
6
5
4
3
2
1
0
-1
Agri
Met min
Coal
Oil, gas
Nonfuel min
Construction
Food
Tobacco
Textiles
Apparel
Lumber
Furn, fixt
Paper
Print, pub
Chemicals
Petroleum
Rub, plastics
Leather
Stn,clay,glass
Primary metals
Fab metals
Nonelec mach
Electronic eqp
Motor vehicles
Other trans eqp
Instruments
Miscellaneous
Transportation
Communication
Electric serv
Gas serv
Trade
F,I,RE
Services
Gov't ent

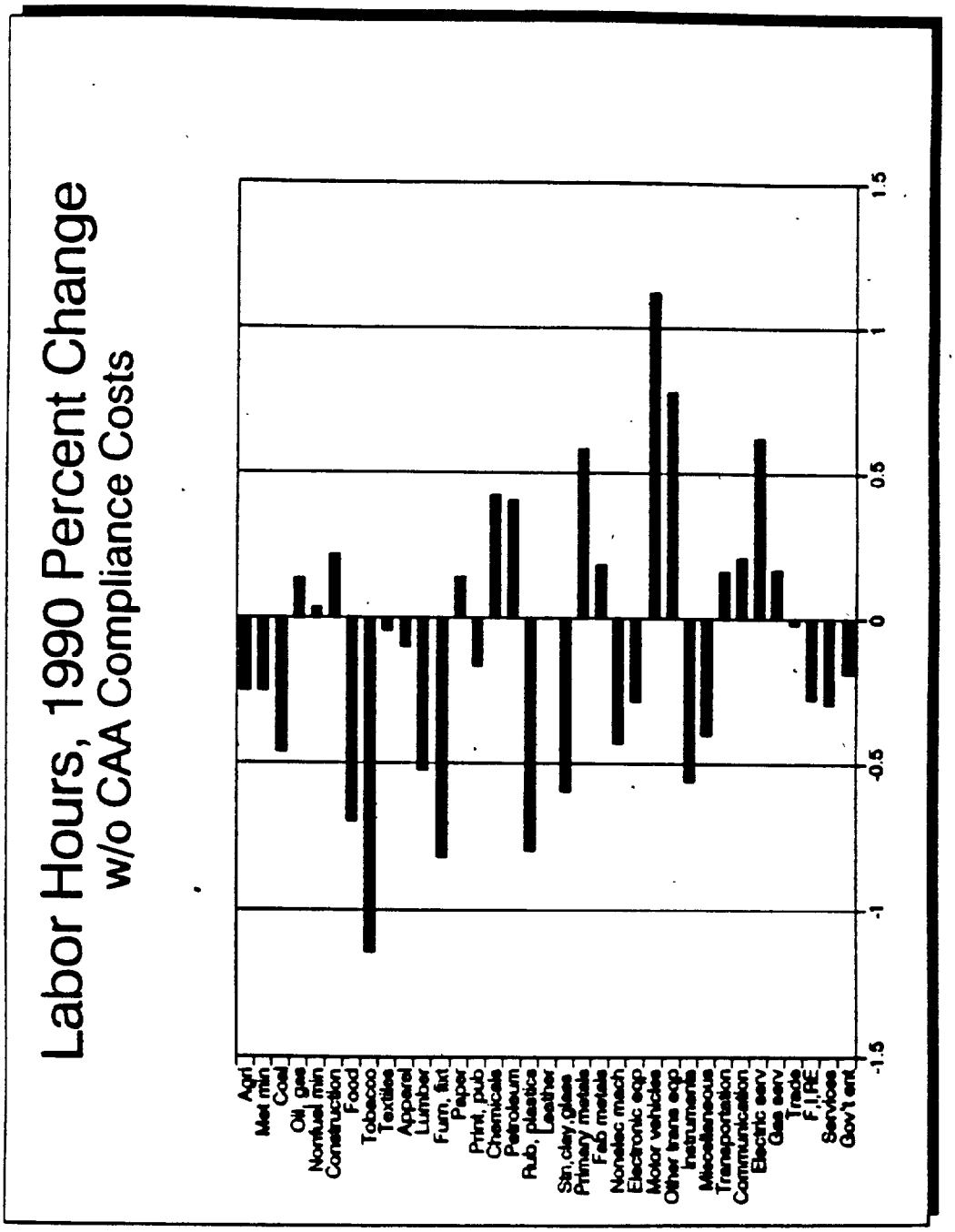
products, motor vehicles and other transportation equipment, and electricity and gas supply. Indirectly, these increases and the increased relative importance of investment goods stimulate mining (energy and non-energy alike), the metals industries and transportation and communication services. Indeed, only a few sectors contract upon removal of the CAA costs. These include food and tobacco, furniture and fixtures, rubber and plastics, electronic equipment and high technology instruments, and services. In broad terms, compliance with the CAA is partly responsible for accelerating the transition of the US. industrial landscape - a transition char is marked by the declining relative importance of basic industries.

While households slightly reduce their overall supply of labor services, the variations in labor input by industry arc somewhat larger. The sectoral changes in labor input are shown in Figure 4.7. With reductions in the relative prices of capital, energy and materials inputs, price-induced substitutions for labor occur in all sectors. These substitution effects can be reinforced by output effects; chat is, output declines requiring less labor as in the cases of food, furniture and fixtures, electronic equipment, services, et. al. Alternatively, they can be partially, exactly (as in the case of leather and leather products) or more than offset by them; that is, output increases requiring more labor as in the cases of metal mining, petroleum refining, primary metals, motor vehicles, electric utilities, et.al. Twenty sectors experience reductions in the use of labor services. Of these, eight also show output reductions while substitution effects dominate output effects in the remaining twelve. Fourteen sectors show increases in labor input. Here, the output effects dominate so labor input rises while labor-output ratios decline.

4.3 Economic Welfare and the Clean Air Act

This section summarizes the estimated welfare changes prompted by the elimination of the CAA compliance costs. In the JWS model, the household sector comprises a number of infinitely lived households. These are distinguished by family size (ranging from 1 to 7 or more persons), age of head (ranging from 16-24 to 65 and over), region of residence (Northeast, Midwest, South, West), race (white, nonwhite), location or type of residence (nonfarm, farm), sex of household head (male, female) and lifetime expenditure (12 categories). This yields 1344 household types within each lifetime expenditure category for a total of 16,128 distinct household groups.

Figure 4.7


Labor Hours, 1990 Percent Change
w/o CAA Compliance Costs
1.5
1
0.5
0
-0.5
-1
-1.5
Agri
Met min
Coal
Oil, gas
Nonfuel min
Construction
Food
Tobacco
Textiles
Apparel
Lumber
Furn, fixt
Paper
Print, pub
Chemicals
Petroleum
Rub, plastics
Leather
Stn,clay,glass
Primary metals
Fab metals
Nonelec mach
Electronic eqp
Motor vehicles
Other trans eqp
Instruments
Miscellaneous
Transportation
Communication
Electric serv
Gas serv
Trade
F,I,RE
Services
Gov't ent

Each household takes commodity prices and interest rates as given and is endowed with perfect foresight (rational expectations). All households face the same prices for goods and services at time *t* and the same nominal interest rate, that is, markets are national. The starting or initial-period distribution of total expenditure within and across each of the 1344 household type is developed from the Bureau of Labor Statistics' *Consumer Expenditure Survey(s).* Expenditure growth for each household occurs at the optimal inter-temporal rate for the economy as a whole. Taken together, these conditions imply that the dynamic processes of expenditure growth and relative price formation impose no further distributional burden. For example, there are no regional growth differentials in incomes, expenditures or relative prices and interest rates; there is no further discrimination on the basis of race or sex; the "poor" do not get poorer while the "rich" get richer. It also means that great care must be taken in interpreting the results for policies which have clear, measurable and unambiguous impacts on regional price or income-expenditure differentials.

Before presenting the results, it is useful to discuss the rationale for choosing equivalent variations as the measure of changes in household welfare. Compensating variations (CV's) measure the change in income that offsets a given change in prices. Stated another way, they measure the change in income necessary to restore a household to their initial welfare level under the new price regime. Equivalent variations (EV's) measure the change in income under the original price regime that yields the same change in welfare that follows from the new price situation. (Note that the change in welfare from a given change in prices is equal and opposite to the change in welfare that results from an opposite change in prices. Therefore, the EV arising from a move from price regime I to price regime II is the same as the CV associated with the move from price regime II to price regime I.) The advantage of EV's over CV's is that the former permits a unique ordering among any number of economic alternatives (because all evaluations are performed under the same original price regime) whereas the latter permits only pairwise comparisons of an alternative situation to the initial situation (that is, CV comparisons among alternatives are not necessarily transitive). EV comparisons permit rankings of more than two alternatives from most to least preferred.

Tables 4.3 and 4.4 present the equivalent variations in lifetime expenditure for a reference household (Family size of four headed by a white male, age 35-44, living in the urban Northeast) and other types differing in one demographic characteristic. The equivalent variations are given for low, medium and high levels of lifetime expenditure. Households with low (high) lifetime expenditure

Table 4.3
Equivalent Variations And Social Welfare

Equivalent Variations in Lifetime Expenditure upon Elimination of the CAA Compliance Costs
1990 Dollars

	Size						
	Size 1	Size 2	Size 3	Size 4	Size 5	Size 6	Size 7+
Low	4359	4412	4400	4334	4360	4262	4248
Med	8340	8448	8422	8292	8341	8147	8120
High	15927	16142	16090	15830	15930	15540	15487

	Age					
	16-25	25-34	35-44	45-54	55-64	65+
Low	4596	4440	4334	4292	4254	4207
Med	8815	8502	8292	8206	8129	8036
High	16874	16249	15830	15658	15505	15318

	Region				*Race*	
	NE	Midwest	South	West	White	NWhite
Low	4334	4384	4262	4338	4334	4078
Med	8292	8391	8147	8300	8292	7780
High	15830	16027	15541	15848	15830	14807

	Locale		*Sex*	
	NFarm	Farm	Male	Female
Low	4334	4434	4334	4255
Med	8292	8491	8292	8132
High	15830	16227	15830	15509

Reference household: Size 4, Age 35-44, Northeast, Nonfarm, White, Male
Low, medium and high refer to the time paths of total expenditure equal to one half the average, the average, and twice the average of total lifetime expenditure.

Table 4.4
Equivalent Variations And Social Welfare

Equivalent Variations as a Proportion of Lifetime Expenditure upon Elimination of the CAA Compliance Costs

	Size						
	Size 1	Size 2	Size 3	Size 4	Size 5	Size 6	Size 7+
Low	.00884	.00895	.00892	.00879	.00884	.00864	.00861
Med	.00846	.00857	.00854	.00841	.00846	.00826	.00823
High	.00807	.00818	.00816	.00802	.00808	.00788	.00785

	Age					
	16-25	25-34	35-44	45-54	55-64	65+
Low	.00932	.00900	.00879	.00870	.00862	.00853
Med	.00894	.00862	.00841	.00832	.00824	.00815
High	.00855	.00824	.00802	.00794	.00786	.00777

	Region				*Race*	
	NE	Midwest	South	West	White	NWhite
Low	.00879	.00889	.00864	.00880	.00879	.00827
Med	.00841	.00851	.00826	.00842	.00841	.00789
High	.00802	.00812	.00788	.00803	.00802	.00751

	Locale		*Sex*	
	NFarm	Farm	Male	Female
Low	.00879	.00899	.00879	.00863
Med	.00841	.00861	.00841	.00824
High	.00802	.00823	.00802	.00786

Reference household: Size 4, Age 35-44, Northeast, Nonfarm, White, Male
Low, medium and high refer to the time paths of total expenditure equal to one half the average, the average, and twice the average of total lifetime expenditure.

have a time path of total expenditure that is one-half (double) of those with average lifetime expenditure. The medium lifetime expenditure level corresponds to the time path of expenditure equal to chose of average Lifetime expenditure. As indicated, expenditure *growth* is the same in all categories.

The cables show *positive* equivalent variations for all households. For the reference household with medium lifetime expenditure, elimination of the CAA compliance costs is equivalent to a gain of $(1990) 8,292 which represents just over 0.8 percent of lifetime expenditure. The minimum and maximum percentage gains in lifetime expenditure for all households are 0.7 and 0.9 percent, respectively. The EV's increase with lifetime expenditure but the gains are proportionally larger for low expenditure households than for high expenditure households. This implies that elimination of the CAA compliance costs is progressive or, conversely, their imposition is regressive.

As illustrated graphically in Figure 4.8 and for a given level of lifetime expenditure (medium), the gains are generally smaller for larger households, smaller for older households, smaller for non-Midwesterners (especially Southerners), smaller for nonwhites and females, and smaller for urban residents. This means that the losses from the costs associated with CAA enactment fall more heavily on smaller, younger, rural Midwestern households headed by white males.

Table 4.5 presents welfare changes for society as a whole. Here, the elimination of the CAA compliance costs secures a welfare gain of $(1990) 493 billion when the greatest weight is given to equality and $(1990) 621 billion when the least weight is given to equality. These amounts represent 0.5 and 0.6 percent of total lifetime expenditure, respectively, over the period 1973-2060. The aggregation of individual welfare is accomplished under a rule of redistribution in which inter- and intra-temporal transfers of expenditures from those with higher welfare to those with lower welfare are welfare improving for society as a whole. Under this scheme, the best that is achievable is that allocation of expenditure that allows each household to achieve the highest attainable average level of welfare. An unequal distribution of welfare among households imposes a welfare loss from this highest attainable level, the losses being larger the more averse society is to inequality or, equivalently, the more weight society puts on equality. Thus, eliminating the CAA costs yields a welfare gain of $(1990) 703 billion independent of equity considerations. When equity is considered, there is a loss in welfare of $(1990) 209 billion when society gives the most weight to equality and $(1990) 82 billion when society gives the least weight to equality.

Figure 4.8

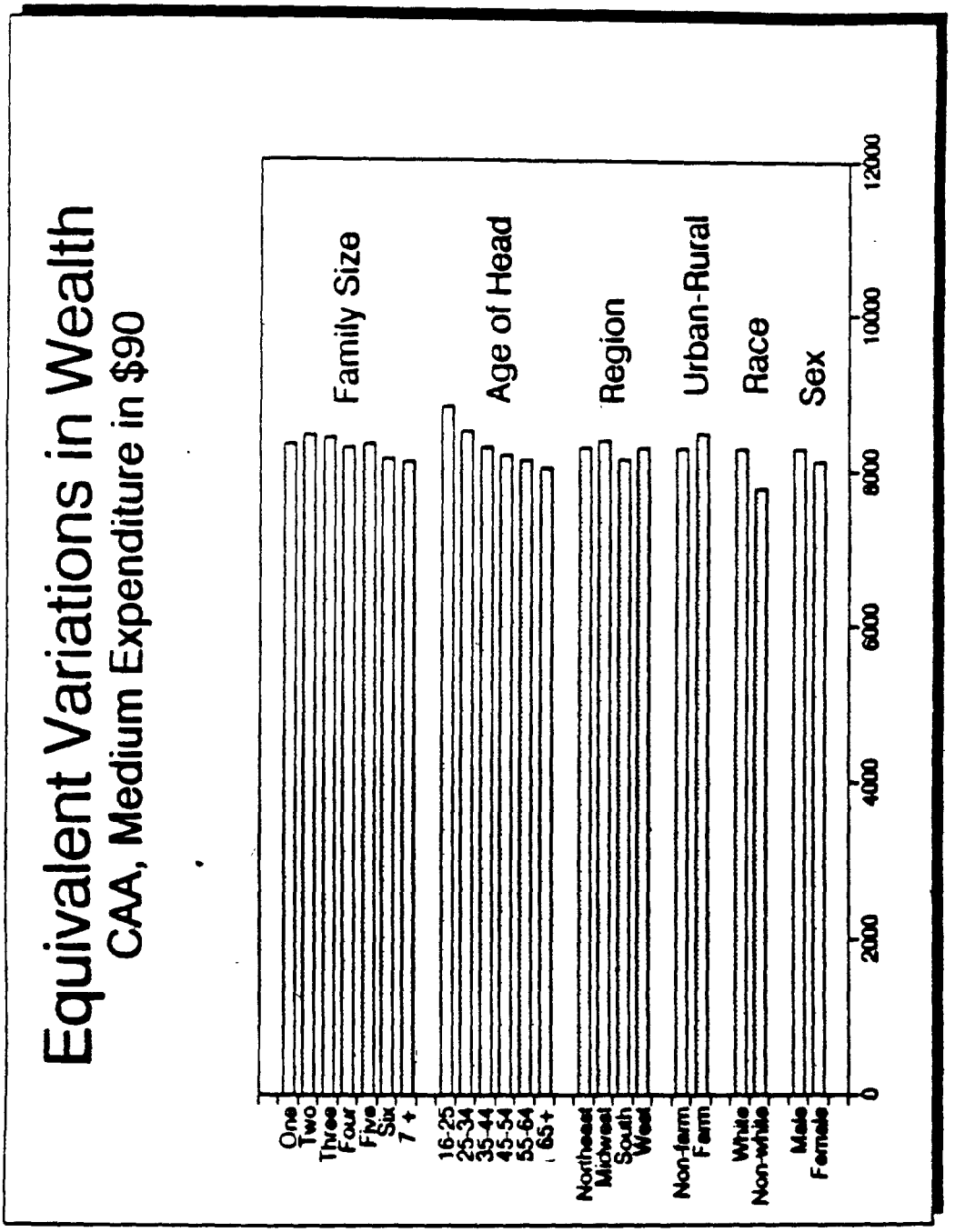

Equivalent Variations in Wealth
CAA, Medium Expenditure in $90
Family Size
One
Two
Three
Four
Five
Six
7 +
Age of Head
16-25
25-34
35-44
45-54
55-64
65+
Region
Northeast
Midwest
South
West
Urban-Rural
Non-farm
Farm
Race
White
Non-white
Sex
Male
Female
0
2000
4000
6000
8000
10000
12000

Table 4.5
Summary of Social Welfare Changes

Change in Social Welfare upon
Elimination of the CAA Compliance Costs
Billions of 1990 Dollars

Weight given to equality	Welfare	Efficiency	Equity
Greatest	493	703	-209
Last	621	703	-82

Change in Social Welfare as a
Proportion of Lifetime Expenditure

Weight given to Equality	Welfare	Efficiency	Equity
Greatest	.00467	.00679	-.00203
Least	.00600	.00679	-.00079

Index of Relative Progressivity

Weight given to equality	Index
Greatest	.00061
Least	.00075

Elimination of the CAA costs is regressive in the absolute sense (i.e., wealthier households gain more in absolute dollars) but progressive in the relative sense (wealthier households gain proportionally less). Thus, regardless of the weight given to distributional equality, there is a welfare loss arising from the costs of CAA compliance and the imposed costs are regressive to total expenditure.

5. The Economy Welfare and Stationary and Mobile Source Compliance Costs

One aspect of uncertainty in the CAA retrospective assessment concerns the compliance costs for mobile sources. There are large differences between the figures developed by the U.S. Environmental Protection Agency (EPA) and those reported elsewhere. To ascertain the potential consequences of these differences, two additional simulations are considered. The first involves EPA's mobile source compliance costs in isolation. The second examines the impacts of alternative cost estimates, namely those developed by the U.S. Department of Commerce's Bureau of Economic Analysis (BEA).

The EPA compliance costs covered in this analysis relate to both stationary and mobile sources of air pollution. Thus, as a preliminary step, it is useful to examine the consequences of these in isolation. The economic consequences of these alternatives are summarized in Table 5.1 and Figures 5.1 and 5.2. (Supporting graphs for these simulations appear in Appendix B.) Elimination of all CAA costs boosts income and spending by an average of 0.7 percent, 1973-1990. The capital stock expands by an average of 0.9 percent and consumption of goods, services and leisure increases by an average of 0.2 percent. Mobile source compliance costs account for approximately one-third of these total impacts with stationary sources account for the remaining two-thirds.

For selected industries, the mobile source costs are even more important. The elimination of all compliance costs increases petroleum and motor vehicles demand by averages of 3.3 and 4.2 percent, respectively, 1973-1990. Mobile source costs contribute 2.5 and 4.0 percentage points, respectively, to these totals whereas stationary sources account for very little of the impacts on these two sectors. (The details of commodity supplies and prices and labor inputs are presented in Appendix B.)

Table 5.2 and Figures 5.3 and 5.4 summarize the welfare effects associated with the EPA costs. (The standard tables covering welfare impacts appear in Appendix B.) Stationary sources again account for two-thirds of the overall impact. For individual households and for society as a whole, removing the costs associated with stationary sources secures benefits at the rate of two to one over removing the costs for mobile sources. Both types of compliance costs are progressive in removal or, equivalently, regressive upon imposition. Also, for

Table 5.1
Mobile Source Compliance Costs

The Average Percentage Change in Selected Economic Measures, 1973-1990

	Without All CAA Costs	Without EPA Mobile Only	Without BEA Mobile Only
Capital Stock	+0.9	+0.3	+0.4
Household Income	+0.7	+0.3	+0.5
Consumption	+0.7	+0.2	+0.4
Consumption, Leisure	+0.2	+0.1	+0.1
Motor Vehicles	+4.2	+4.0	+8.2
Petroleum Refining	+3.3	+2.5	+2.7

All variables originally are measured in billions of 1982 dollars. The percentage differences are computed for each year relative to the base simulation, i.e., with the CAA and endogenous productivity growth. The average percentage changes over the period 1973-1990 then are determined.

Figure 5.1

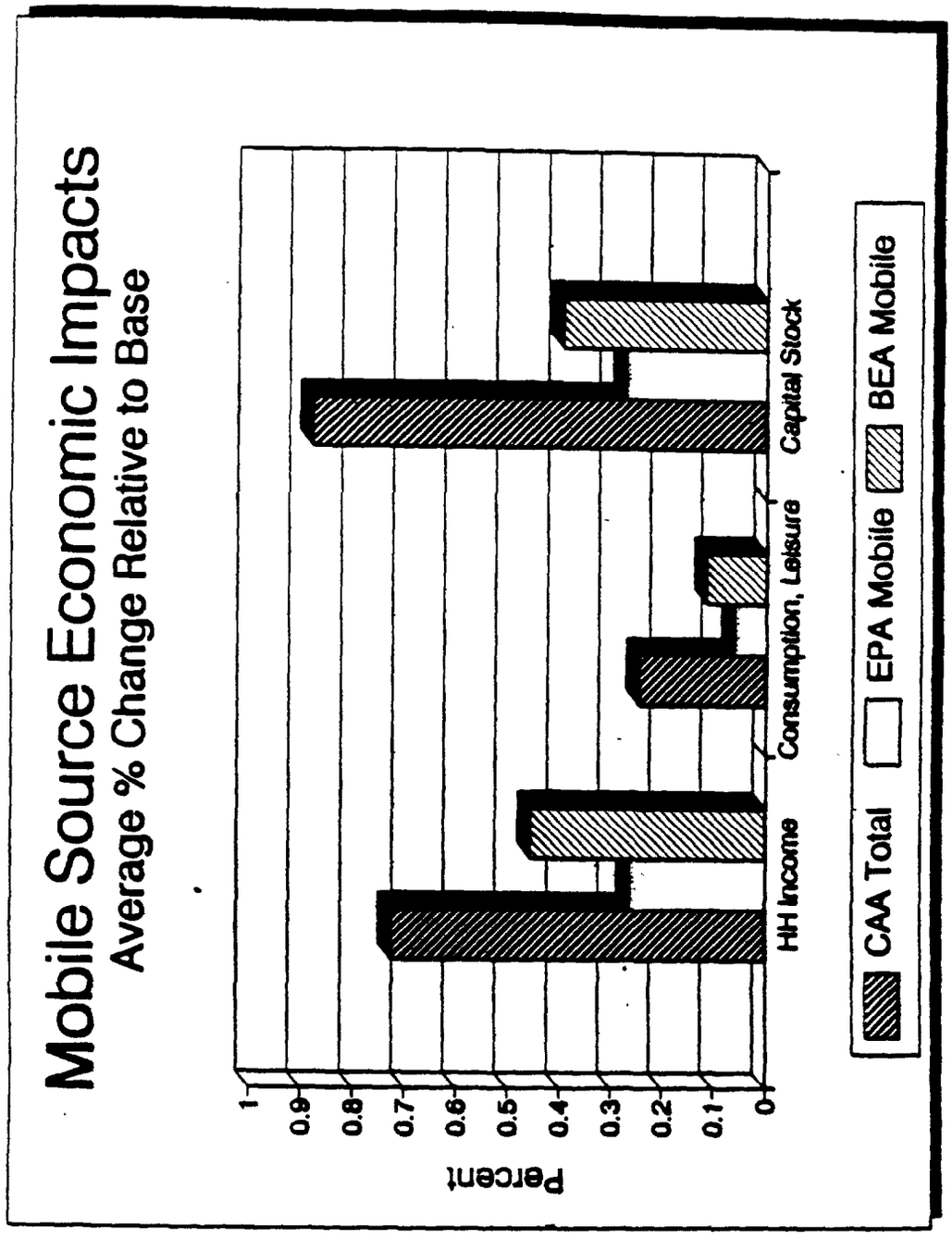

Mobile Source Economic Impacts
Average % Change Relative to Base
Percent
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
HH Income
Consumption, Leisure
Capital Stock
CAA Total
EPA Mobile
BEA Mobile

Figure 5.2

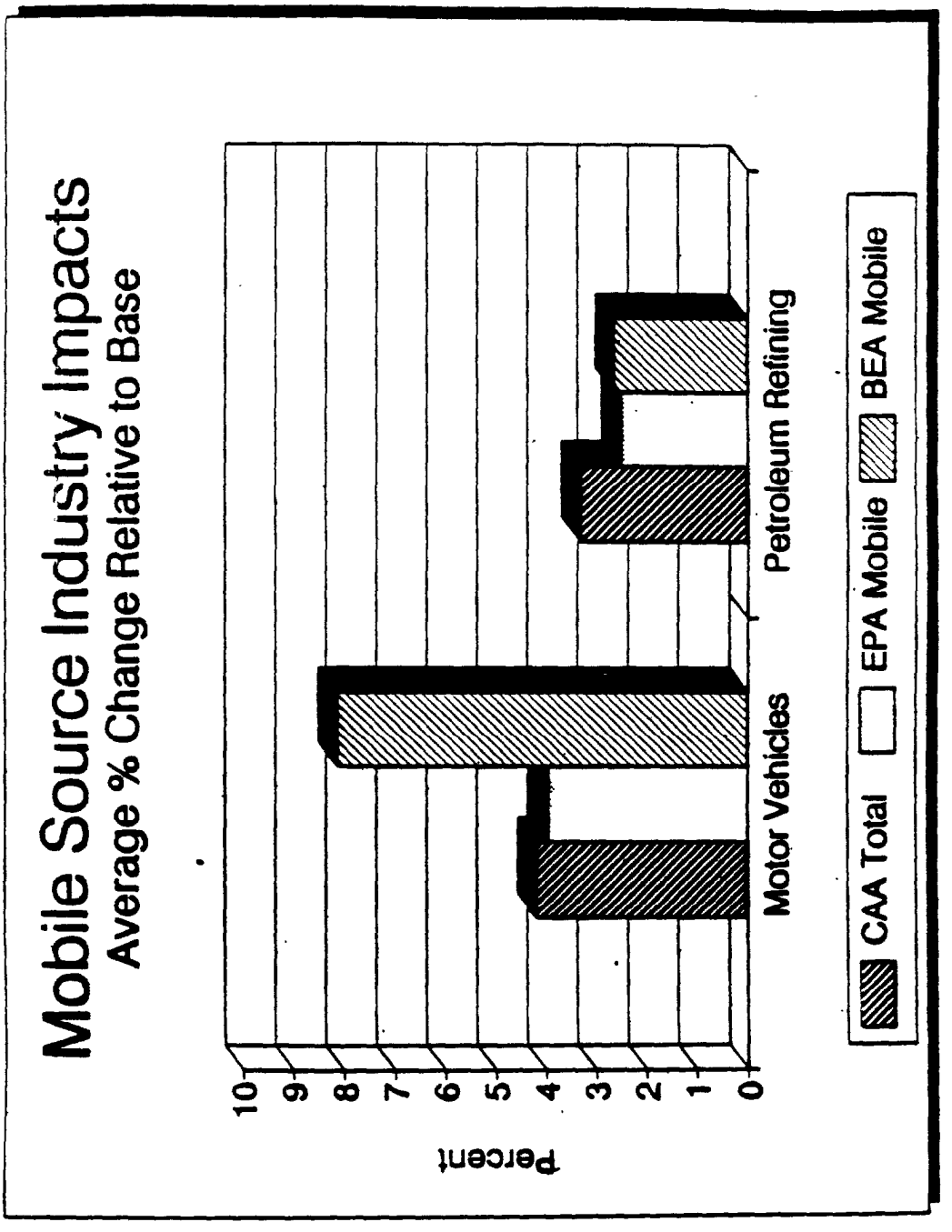

Mobile Source Industry Impacts
Average % Change Relative to Base
Percent
10
9
8
7
6
5
4
3
2
1
0
Motor Vehicles
Petroleum Refining
CAA Total
EPA Mobile
BEA Mobile

Table 5.2
Compliance Costs And Social Welfare
EPA Stationary And Mobile Sources

The Change in Social Welfare
Greatest Weight Given to Equality
Billions of 1990 Dollars

		EPA Total	EPA Mobile	EPA Stationary
Without CAA				
	Welfare	493	156	337
	Efficiency	703	201	502
	Equity	-209	-45	-164

EPA stationary determined as the difference between EPA's CAA total and mobile welfare effects. Errors in differences or balances are due to rounding.

Figure 5.3

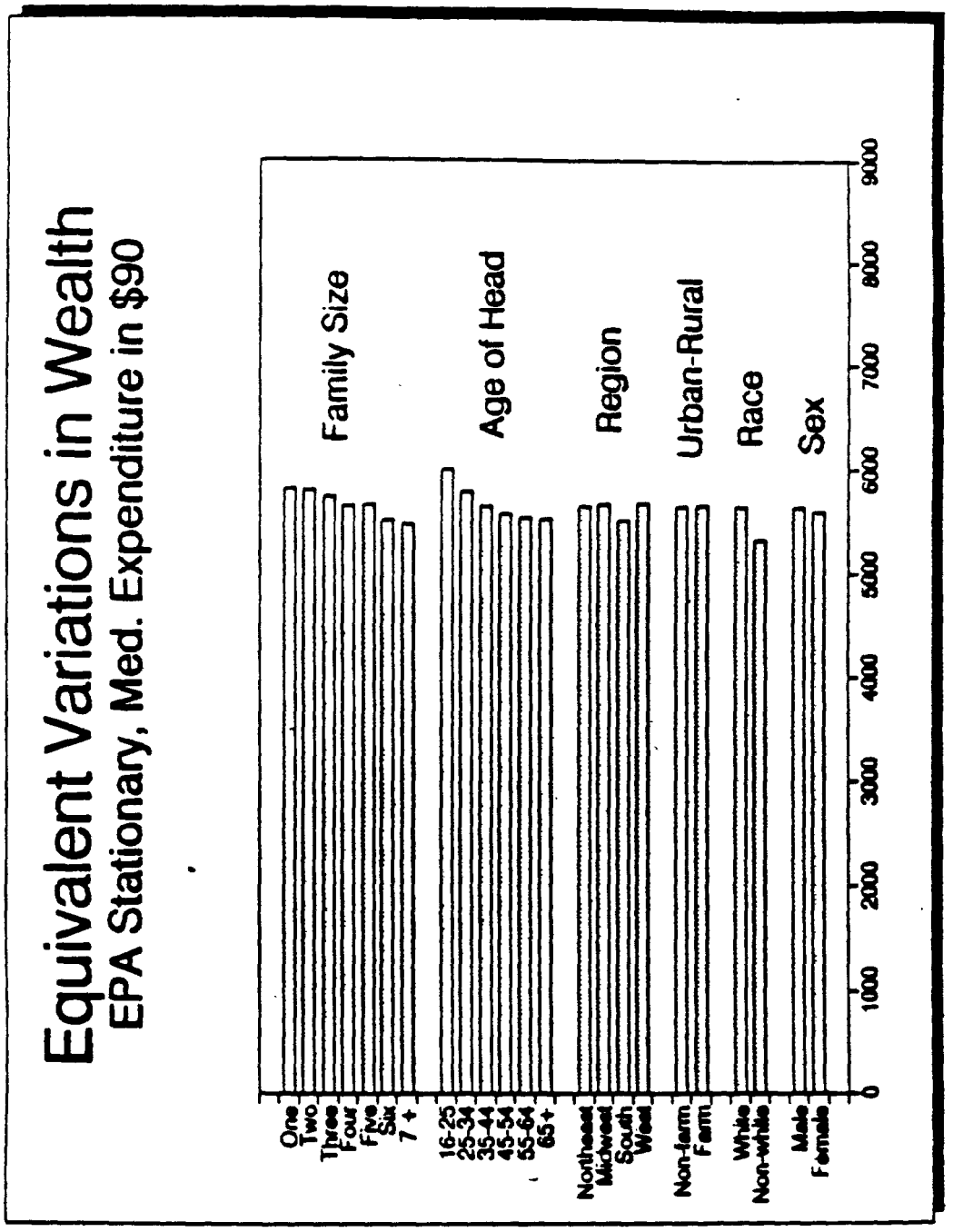
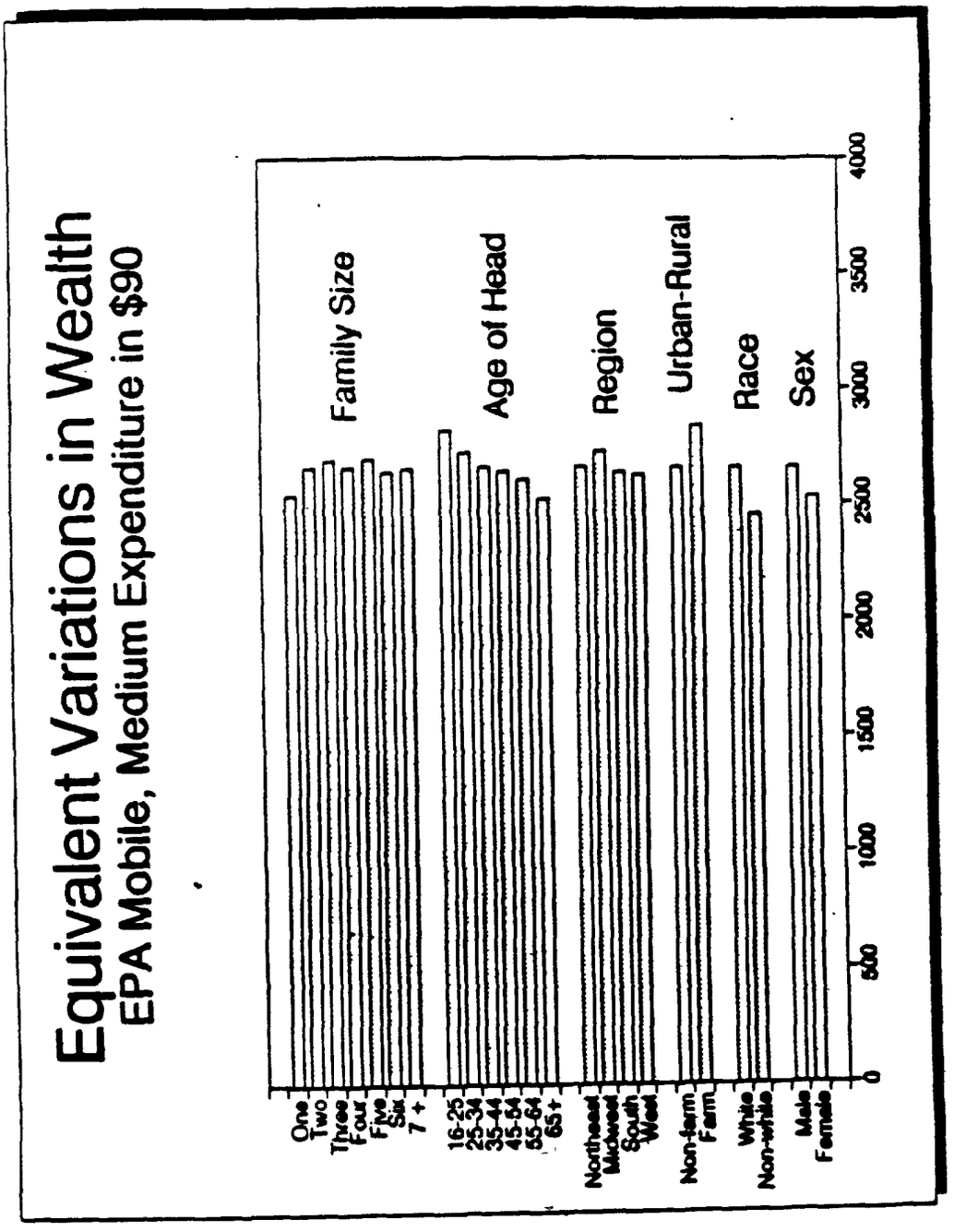

Equivalent Variations in Wealth
EPA Stationary, Med. Expenditure in $90
Family Size
One
Two
Three
Four
Five
Six
7+
Age of Head
16-25
25-34
35-44
45-54
55-64
65+
Region
Northeast
Midwest
South
West
Urban-Rural
Non-farm
Farm
Race
White
Non-white
Sex
Male
Female
0
1000
2000
3000
4000
5000
6000
7000
8000
9000

Figure 5.4


Equivalent Variations in Wealth
EPA Mobile, Medium Expenditure in $90
Family Size
One
Two
Three
Four
Five
Six
7+
Age of Head
16-25
25-34
35-44
45-54
55-64
65+
Region
Northeast
Midwest
South
West
Urban-Rural
Non-farm
Farm
Race
White
Non-white
Sex
Male
Female
0
500
1000
1500
2000
2500
3000
3500
4000

both types of costs, the gains from elimination are larger for younger households and for households headed by whites.

Of more interest are the distributional differences among the incidences of these costs. For stationary sources, the gains are larger for smaller households whereas the reverse is observed for mobile sources. For stationary sources, the gains are approximately equal for households in the Northeast, Midwest and West with the gains for the South being smaller. For mobile sources, the gains are approximately equal for households in the Northeast, South and West with the gains for the Midwest being larger. For stationary sources, the. gains are approximately equal for nonfarm and farm residences and for households headed by males and females. For mobile sources, the gains for farm residences and households headed by males exceed those for nonfarm and female-headed households. Clearly, the resulting patterns of expenditures and relative prices differ for the two types of compliance costs and, not surprisingly, different types of households are affected differently by each.

The EPA and BEA mobile source cost data are distinguished in Table 5.3. There are large differences between the figures developed by EPA and those from BEA. For example, EPA's estimates of the capital component of mobile source compliance costs are roughly half those of the BEA. Both agencies recognize the benefits to vehicle maintenance arising from compliance with the CAA provisions. But, EPA estimates an average benefit of $2.4 billion, 1973-1990, while BEA estimates an average cost of $0.5 billion over the same interval. The fuel components of mobile source compliance costs are closer on average between the two agencies. However, there are substantial differences in timing and annual magnitudes. EPA's estimates are more uniform over the period 1973-1990 with the cost differential for producing unleaded gasoline playing an important role. BEA's estimate of the fuel-related costs are comparatively high in the early to mid-1980's and comparatively low earlier and later in the interval. For BEA, the market price differential between regular and unleaded gasoline plays a dominant role.

Table 5.1 and Figures 5.1 and 5.2 also permit comparisons to the effects of mobile source compliance costs as estimated by the Bureau of Economic Analysis (BEA). If mobile source compliance costs were of the magnitude of the BEA estimates, their elimination would yield improvements in overall economic performance that are 40, 60 and, even, 100 percent larger than those arising from the EPA estimates. For example, capital expansion is 45 percent greater, BEA versus EPA; the impact on the consumption of goods, services and

Table 5.3
Mobile Source Compliance Costs

Compliance Costs in Billions of Current Dollars

EPA Estimates

	Capital	Maintenance	Fuel Price Penalty	Fuel Economy Penalty
Average	4.1	-2.4	1.8	1.0
1973	0.3	-0.0	0.1	1.7
1990	7.3	-5.1	3.8	-0.5
Peak Value	7.3	-0.0	3.8	2.2
Peak Year	1990	1973	1990	1975

BEA Estimates

	Capital	Maintenance	Fuel Price Penalty	Fuel Economy Penalty
Average	8.3	0.5	2.3	1.2
1973	1.0	1.1	0	0.7
1990	14.5	-0.7	1.4	-0.1
Peak Value	16.2	1.5	5.0	2.3
Peak Year	1988	1975	1985	1980

leisure is 84 percent greater; the effect on real household income is 72 percent greater; the average percentage increase in motor vehicle demand is more than double, from just under 4 percent (EPA) to just over 8 percent (BEA). This, of course, has important implications for labor inputs into this sector. With EPA mobile source costs, labor inputs into motor vehicles increase by almost 1.5 percent in 1990. The corresponding figure with BEA mobile source costs exceeds 2.5 percent, almost double the impact with EPA costs. Only the increases in petroleum demand are comparable, with the BEA costs yielding an average 2.7 percent increase in demand compared to 2.5 percent for the EPA costs. (Appendix B contains figures that compare macroeconomic and industry performance and labor input considerations.)

As expected, the scale of the welfare effects associated with the BEA mobile source data and shown in Table 5.4 is substantially larger than that observed for the EPA mobile costs. In fact, the welfare gains from removing the BEA mobile source costs are on a par with those estimated for the EPA stationary source costs (compare Figure 5.5 and 5.3) and are twice the size of those arising from the EPA mobile costs (compare Figure 5.5 and 5.4). As indicated above, the BEA cost figures not only differ in scale but also in composition. These differences lead to variations in the incidences of the gains among households with different demographic attributes. Indeed, the patterns that emerge from the BEA mobile figures are similar to those associated with the EPA stationary costs. That is, the gains are larger for smaller households, larger for younger households, smaller for Southern households (and comparable among the other regions), smaller for nonwhite households and approximately equal between farm and nonfarm households and households headed by males and females (Figure 5.5).

If the mobile source compliance costs were of the magnitude of the BEA estimates, their elimination would yield improvements in overall economic welfare beyond those arising from the EPA estimates. For example, if the effects arc additive, the overall welfare gain would rise by $(1990) 137 billion (or, 28 percent) and the efficiency gain would increase by $(1990) 240 billion (or, 34 percent). Clearly, mobile source costs are important to assessing the overall impact on welfare of the CAA and, equally clear, the larger the direct effects on prices and costs the larger the changes in economic welfare.

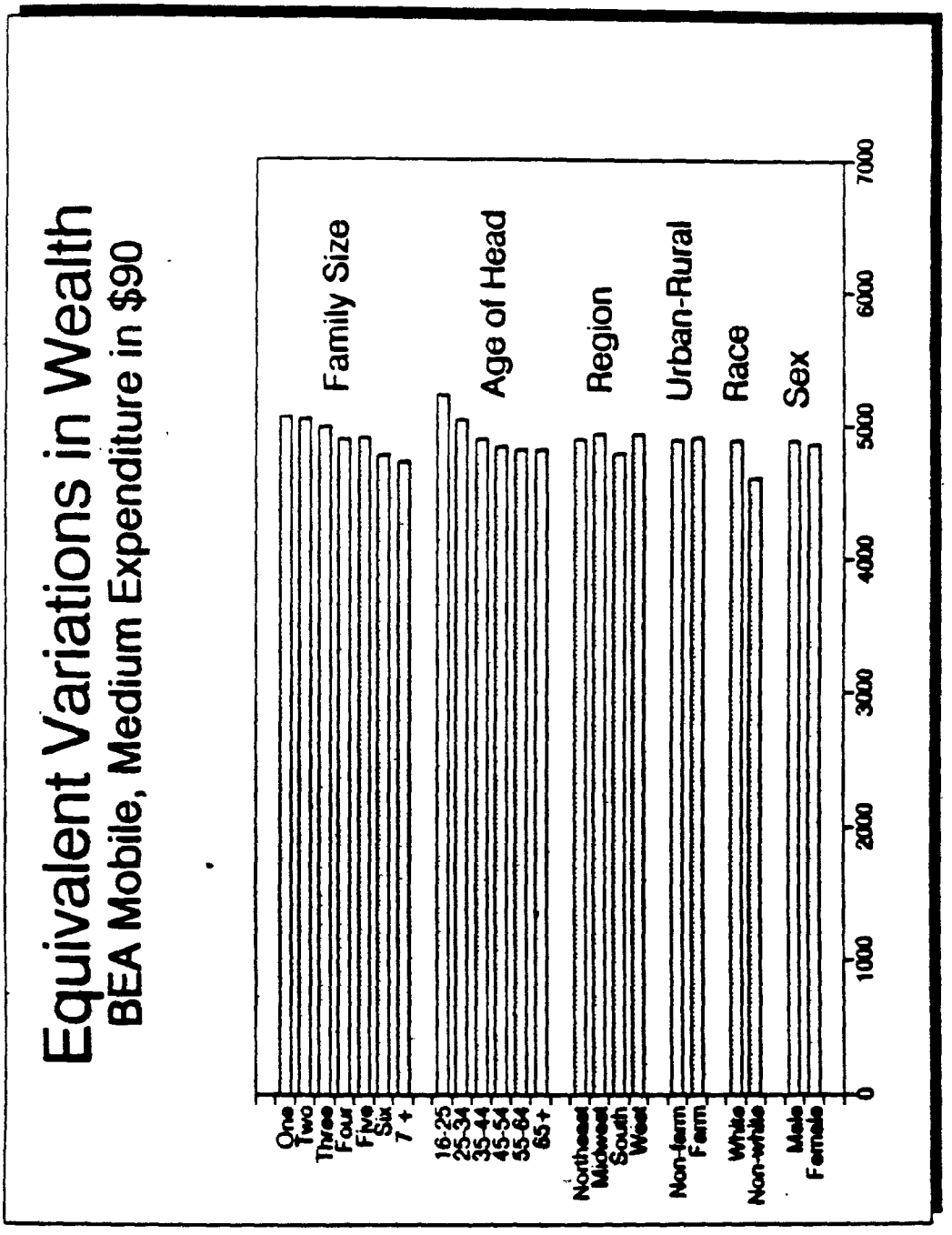
Table 5.4
Compliance Costs And Social Welfare
EPA And BEA Mobile Sources

The Change in Social Welfare
Greatest Weight Given to Equality
Billions of 1990 Dollars

		BEA Mobile	EPA Mobile	Difference
Without CAA				
	Welfare	293	156	137
	Efficiency	441	201	240
	Equity	-146	-45	-101

EPA stationary determined as the difference between EPA's CAA total and mobile welfare effects. Errors in differences or balances are due to rounding.

Figure 5.5


Equivalent Variations in Wealth
BEA Mobile, Medium Expenditure in $90
Family Size
One
Two
Three
Four
Five
Six
7 +
Age of Head
16-25
25-34
35-44
45-54
55-64
65+
Region
Northeast
Midwest
South
West
Urban-Rural
Non-farm
Farm
Race
White
Non-white
Sex
Male
Female
0
1000
2000
3000
4000
5000
6000
7000